



Experimental Gravel Bar Habitat Creation in the Tombigbee River, Mississippi

by Andrew C. Miller

PURPOSE: Prior to development of the Tennessee Tombigbee Waterway (TTW), the Tombigbee River was well-known for supporting a dense and diverse fauna including sculpins, minnows, mussels, snails, worms, and immature insects. Completion of this project dramatically altered the habitat characteristics of the river, converting free-flowing pool and riffle sequences to a series of reservoirs. Resource agencies expressed some concerns over the loss of shallow riffle habitat, since large numbers of state-listed endangered organisms, plus five species of molluscs and three species of fishes that were undergoing a status review at that time were potentially affected (U.S. Fish and Wildlife Service (USFWS) 1980a, 1980b).

In response to these concerns, a shallow-water gravel habitat was designed and created to mimic those conditions existing in the Tombigbee River prior to development of the TTW (Figure 1). This technical note describes the design and construction of this gravel bar and the subsequent development of the biotic community.

BACKGROUND: The TTW, authorized by Public Law 525 in accordance with recommendations contained in House Document 486 in the 79th Congress, was designed to provide a more direct shipping route between the eastern gulf coast and the mid-continental United States. This was done by connecting the upper portion of the Tombigbee River to the Tennessee River in northeastern Mississippi (Brose 1991). This converted the free-flowing Tombigbee River into a series of run-of-the-river reservoirs.



Figure 1. Gravel bar habitat in the upper end of an abandoned channel of the Tombigbee River, Mississippi, immediately after construction, 1985

USACE responded to criticism of the TTW by convening an interdisciplinary Environmental Board, whose task was to develop strategies to minimize negative impacts of aquifer drawdown,

¹ This technical note serves as an update to information presented in Technical Note EEDP-07-4 (Miller 1988).

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waterlogging, water quality changes, interbasin transfer and mixing of species from different watersheds, endangered species issues, erosion, sedimentation, and habitat loss associated with the TTW (McClure 1985). The issue of habitat loss was a primary concern, since five mollusk species and three fish species were undergoing a status review at that time (USFWS 1980a, 1980b). Likewise, a large number of state-listed endangered organisms were potentially affected. All were dependent upon riffle habitat, which had been eliminated by construction of the TTW.

The Environmental Board recommended that the U.S. Army Engineer District, Mobile should construct an experimental gravel shoal in an abandoned channel of the Tombigbee River immediately downriver of Columbus Lock and Dam, near Columbus, Mississippi. The shoal was to mimic shallow-water habitat that existed in the Tombigbee River prior to development of the TTW. It would provide sources of food and cover for freshwater mussels, snails, worms, aquatic insects, minnows, and darters. It was not intended as mitigation or compensation for riffle habitat lost by construction of the TTW, but was suggested as a means of studying the problem and providing a demonstration of a possible solution to loss of riverine habitat. After a preliminary study of an existing gravel bar in the nearby Luxapalila River, a plan for the new habitat was submitted to the Mobile District of the U.S. Army Corps of Engineers (King et al. 1982).

SITE DESCRIPTION: The Tombigbee River originates in northeastern Mississippi, flows along the eastern section of the state, and then enters Alabama south of Columbus, Mississippi. In Demopolis, Alabama the river joins with the Black Warrior River, and then flows south along the western two thirds of the state. It joins the Alabama River approximately 35 km north of Mobile, Alabama to form the Mobile River that flows due south into Mobile Bay (Figure 2). The Tennessee River is formed by the confluence of the French Broad and Holston Rivers north of Knoxville in eastern Tennessee. From there it flows southwest into Alabama, then northwest back into Tennessee, then into the western edge of Kentucky, where it enters the Ohio River at mile 933 approximately 77 km (48 miles) upriver of the confluence of the Ohio and Mississippi Rivers.

The Tennessee-Tombigbee Waterway is a 250-mile-long (400 km) waterway that connects the upper end of the south-flowing Tombigbee River with a north-flowing portion of the Tennessee River (Figure 2). The waterway has three sections starting with the Tennessee River: a divide cut made through a drainage system with high topographic relief adjacent to the Tennessee River, a canal section that consists of five locks that have created a narrow chain of lakes, and finally the river section, which consists of four locks and dams on the original Tombigbee River, starting north of Aberdeen, Mississippi and ending at the mouth of the Black Warrior River in Alabama. These latter locks and dams create shallow lakes that are separated by straight river segments located near Aberdeen and Columbus, Mississippi, and Aliceville and Gainesville, Alabama. Completed in 1985, the



Figure 2. The Tennessee Tombigbee Waterway (dotted line) connects the Tombigbee and Tennessee Rivers

Tennessee-Tombigbee Waterway shortened the distance to the Gulf of Mexico by almost 1,290 km (800 miles) (Brose 1991).

PROJECT DESIGN AND CONSTRUCTION: The entrance to Columbus Lake from the south is a short, straight dredged channel that branches off the original Tombigbee River (Figure 3). The original channel of the Tombigbee River ends at the face of the dam. To maintain some flow in this abandoned channel, a minimum flow release structure was installed that releases 5.7 m^3 (200 cfs) of water from the surface of Columbus Lake. The flume downstream of the release structure is approximately 30 m long and 0.4 m wide. Water depth in the flume is between 0.8 and 1.0 m and velocity is approximately 1.0 m/sec. Because the receiving channel is approximately 60 m wide and 3-5 m deep, this discharge produces no measurable flow in the abandoned channel.

The first step in construction of the habitat involved transport of random fill material, consisting primarily of sand, to the upper end of the channel. Sand was placed with a clam shell dredge into an 80-m reach of the channel to an elevation of 39.6 National Geodetic Vertical Datum, which was about 2 m below normal water level. The fill was then capped with 24,000 m^3 of 2- to 80-mm coarse gravel, obtained from an upland site and brought to the site by barge. The habitat was completed in March 1985.

Two exposed bars, with a riffle or channel running down the center of each, were created with the gravel (Figures 4 and 5). Each riffle is 46 m long, 24 m wide, with a water depth of approximately 1.2 m and a velocity of approximately 50 cm/sec. This is sufficient to prevent excess sedimentation but not erode base material (Vanoni 1975). At high discharge rates, the entire habitat, including the exposed gravel, is covered with backwater from the Tombigbee River. Water velocity in the riffles is then zero, since the constriction no longer exists. When water level declines, flow is restricted to the channel and velocities of 50 cm/sec resume, removing any fine-grained settled sediments. Typically this occurs for several weeks or months in the winter, but rarely during the rest of the year. An exception occurs when the gates of Columbus Lock are opened, releasing water from the chamber. Water flows down the dredged channel, and then a portion moves up the abandoned channel, inundating the exposed gravel to a depth of 5 to 20 cm for a

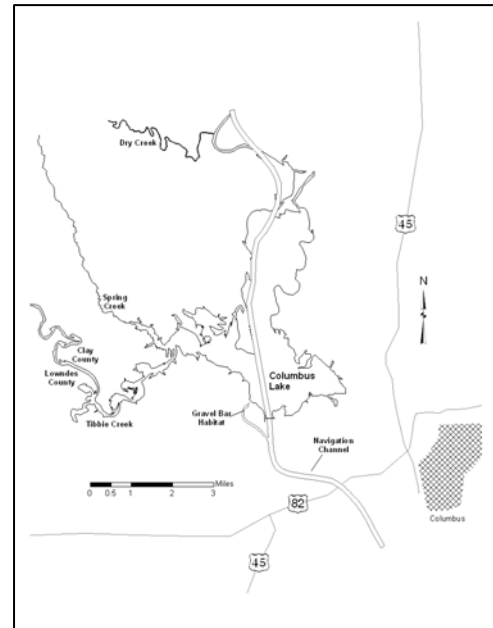


Figure 3. Gravel bars were placed in the north end of an abandoned channel of the Tombigbee River on the southwestern side of Columbus Lake, Mississippi

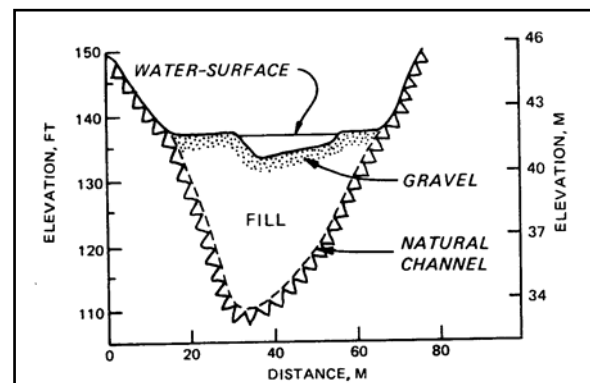


Figure 4. Cross section of gravel bar habitats

few minutes. This temporary inundation, plus the extended submergence during high water, usually in the winter, effectively restricts the vegetation to hydrophilic species such as sedges and water willow.

This design created what is essentially a small fourth-order pool-riffle complex within an eighth-order river system. Water flowing through the riffles is warmed and oxygenated by the lake, since surface water is removed for the minimum flow release structure. Nutrient-rich water, carrying phytoplankton and detritus from the upper watershed, is carried to the gravel bar habitat. Unlike lower ordered streams, there are no erosive flows or spates caused by storm events; the minimum flow release structure will not pass more than $5.7 \text{ m}^3/\text{sec}$. Therefore, velocity is either 50 cm/sec when water is within the channels or essentially zero when the bars are submerged.

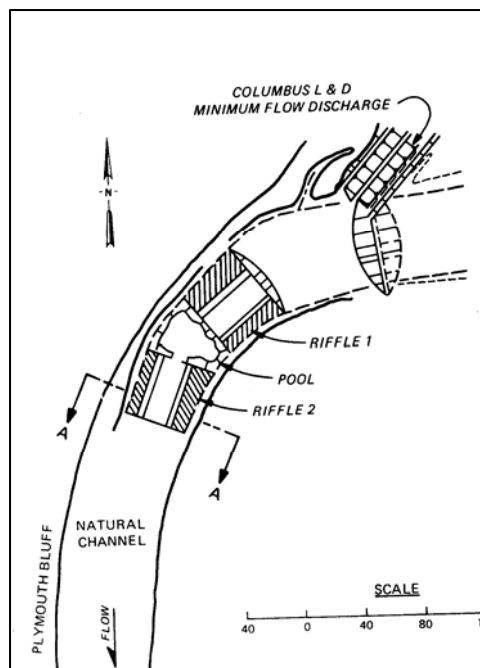


Figure 5. Cross section of gravel bar habitats

HABITAT UTILIZATION

Non-molluscan invertebrates. Invertebrate colonization of the newly placed gravel shoals was rapid. By June of the first year, 3 months after construction, nearly 30 species of macroinvertebrates were collected, and by the fall of the same year nearly 50 were taken (Figure 6). The total number of macroinvertebrate taxa increased slightly over the next three years, with the fall samples always containing more taxa than the spring samples. Species diversity (Shannon's index, H') was less than 1 in 1985, and between 2.5 and 3.0 for the remainder of the study (Figure 7). Low diversity the first year was the result of extreme dominance of Chironomidae before other species had colonized (Miller and Bingham 1987).

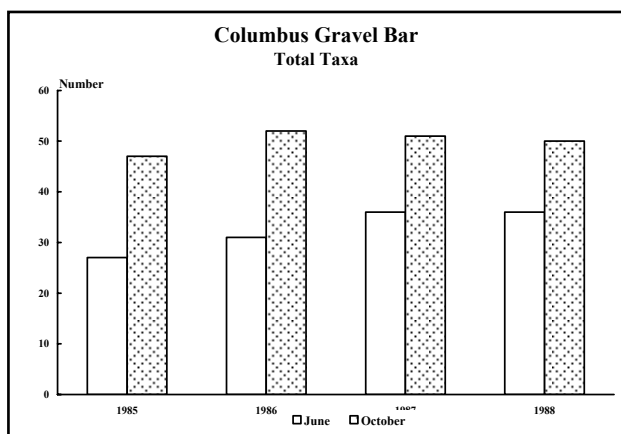


Figure 6. Total macroinvertebrate taxa collected at the Columbus gravel bar site

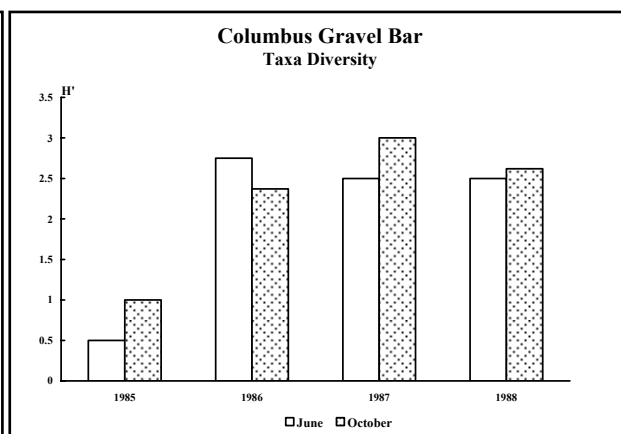


Figure 7. Macroinvertebrate diversity at the Columbus gravel bar site

Mean macroinvertebrate density (individuals/m²) increased during the four-year study period, from approximately 3,000 and 10,000 in June and October of 1985 to more than 21,000 and 45,000 in June and October of 1988 (Figure 8). Total macroinvertebrate abundance was consistently higher in the created gravel bar than in a similar nearby natural gravel bar (Figure 8).

In June 1985, the Chironomid *Glyptotendipes* sp. comprised more than 90 percent of the assemblage. In the fall of the second year, the Chironomidae comprised 50 percent of the assemblage, with the remainder consisting of Asian clams (*Corbicula fluminea*, 20 percent), tubificids (10 percent), trichopterans (6 percent), and others (approximately 15 percent) comprising the remainder of the macroinvertebrates. Chironomidae dominated macroinvertebrate abundance during the first two years, and then declined in importance in 1987 and 1988. The Columbus gravel bars provided habitat for a diverse assemblage of oligochaete taxa. Twenty-eight species of oligochaetes in the families Naididae and Tubificidae were identified in 1985-1987 (Bingham and Miller 1989). In the spring and fall of 1985, 7 and 20 taxa, respectively, were identified. In the spring and fall of 1986, 8 and 18 taxa were identified. Naididae abundance gradually increased during the 3-year survey, whereas Tubificidae were uncommon the first year and then reached a density of 200 – 400 individuals per year in 1986 and 1987. Maximum oligochaete density (Naididae and Tubificidae), approximately 1,000/m², is similar to that reported from non-polluted habitats by other workers. Although densities equal to 8,000 individuals/m² are not uncommon in lakes (Pennak 1953), in streams with sand gravel substratum numbers are usually less. Moffett (1936) reported 42.8 – 492.2 individuals/m² from streams in Utah, and Paloumpis and Starrett (1960) reported average values of 3745/m², 7265/m², and 5885/m² in flood plain lakes in Illinois.

Other studies have also reported rapid rates of colonization by macroinvertebrates. Ciborowski and Clifford (1984) found immature insects on trays of substrata within one day of being placed in flowing water. Shaw and Minshall (1980) demonstrated that the colonization process started almost immediately and continued for at least 64 days. Gore (1979) reported that macroinvertebrates rapidly colonized a reclaimed river channel in 120 days. However, colonization rates are likely to differ according to the life history characteristics of the organisms involved. For example, most naidid worms live near the surface of the substratum, are capable of clumsy swimming, and frequently enter the drift (Milbrink 1973). In contrast, Tubificidae burrow into the substratum, do not drift as readily as the naidids, and most do not colonize the more coarse-grained particulates. In the Columbus gravel bar, the tubificidae were comparatively slow to colonize the gravel bar. These organisms do not have an aerial stage and mainly reach an area by drifting from upstream. Numbers were insignificant the first year, and then became more abundant after the second year. However, due to the coarse-grained sediments of this site, densities of tubificids

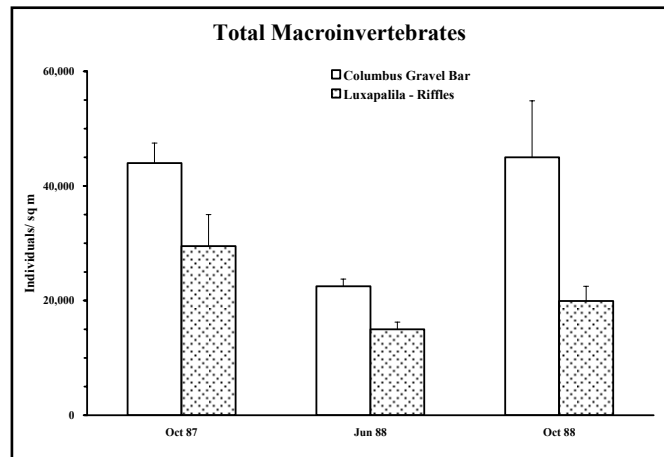


Figure 8. Comparison of macroinvertebrate density at Columbus gravel bar site and a natural gravel shoal on Luxapalila Creek

will likely never approach those that can occur in lentic habitats with organically enriched substratum.

These created gravel bars differed from natural habitats in that sediments were fairly uniform (there were no boulders or large flat rocks), water velocity did not exceed 45 cm/sec, and there were no pool-riffle sequences immediately up or downriver. Because it is isolated from similar habitats, recolonization rates by slowly moving organisms such as the oligochaetes were not as rapid as they would be by other invertebrates. Using sampling techniques similar to those used at the Columbus gravel bar, macroinvertebrate samples were collected from a gravel shoal in nearby Luxapalila Creek (Figure 8). On all three sampling dates, total macroinvertebrate density at the gravel bar exceeded that in Luxapalila Creek. There are no spates at the Columbus site that would remove the fauna, as frequently happens at Luxapalila Creek (Payne and Miller 1991).

Fishes. In 1985-86, fishes were collected and compared among three sites: the created gravel bar, the high-velocity, riprapped flume upriver from the gravel bar, and the abandoned natural channel downriver of the habitat. A total of 42 species of fishes comprising 10 families were collected from the gravel bar and the other two sites. Of these, 39 species were collected at the gravel bar, 25 were found in the channel downriver of the habitats, and 16 were found in the flume. Common taxa included shad, white crappie, bluegill, orange-spotted sunfish, largemouth bass, and minnows. The crystal darter, listed as endangered in the state of Mississippi, was collected once in October 1985. The blue sucker (*Cycleptus elongatus*) was collected on several occasions in the flume directly below the minimum flow release structure. In 1989 the American Fisheries Society added the blue sucker to its list of rare North American fishes (Williams et al. 1989). In 1994 it was listed by the U. S. Fish and Wildlife Service as a Category 2 species.

Species richness was significantly higher ($p < 0.05$) at the gravel bar than at the rip-rapped flume and the river channel downstream of the habitat (Figure 9). Except for the river channel, species richness was highest in May and lowest in December. In the spring, adults ascend streams to spawn and are probably attracted to the gravel and flowing water at the habitat. The flume is essentially a tailwater habitat that can attract fishes by influencing food availability (Walburg et al. 1971) and physical and chemical characteristics (Edwards et al. 1984, Jacobs and Swink 1983). Relatively large fishes (carp, suckers, largemouth bass, catfish, and drum) were collected

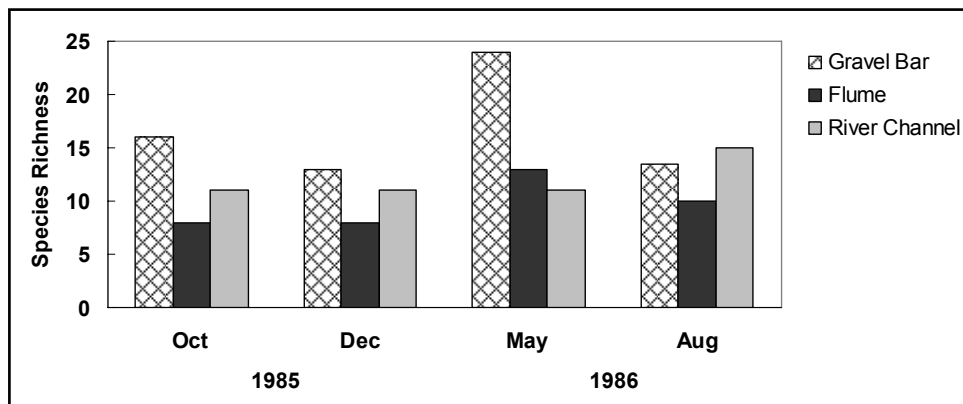


Figure 9. Fish species richness at the Columbus gravel bar, the riprapped flume immediately upriver, and the Tombigbee River Channel located immediately downriver, 1985 and 1986

in the flume upriver from the created gravel bar habitat. These species are often found in high-velocity water where they feed on drifting invertebrates (Walburg et al. 1971).

Catch per unit effort (in minutes), as determined with electro-fishing apparatus, varied considerably among sites and seasons. The highest catch (11.6) was measured in May at the flume and gravel bar, whereas the lowest (2.4) occurred in August in the river channel. Combining all seasons, the catch per minute (\pm standard deviation) at the river channel (5.05 ± 2.56) was significantly lower than at the gravel bar (10.2 ± 1.67) or riprapped flume (8.15 ± 2.74). Gizzard and threadfin shad dominated at all sites. Minnows, shiners, and darters were the second-most abundant group at the gravel bar, and their catch per minute was higher than at the other two sites. Drum and catfish were collected in higher numbers in the flume than at the gravel bar or the river channel. Sunfishes were fairly common at all sites and comprised approximately 20 percent of the total catch. Crappie were most common in the river channel and were relatively uncommon in the shallow water in the riffles or the flume.

Freshwater Mussels. There are approximately 300 species of freshwater mussels (family: Unionidae) in North America, with 55-60 percent considered to be extinct or imperiled (Master 1990, Eisner et al. 1995). Prior to the construction of the TTW, 40 or more species of freshwater mussels were present in the Tombigbee River (Yokley 1978, van der Schalie 1981).

Immediately after construction, juvenile *Obliquaria reflexa*, as well as the introduced Asiatic clam *Corbicula fluminea*, were found at the gravel bar in the benthic samples. *Corbicula fluminea* is an introduced bivalve that does not require a fish host like most unionids (Fuller 1974, Russell-Hunter 1979), and quickly colonizes lotic and lentic habitats in the south. Because not all mussel species can be expected to successfully recruit each year (Payne and Miller 2001), and because of their unusual life history strategy (i.e., the need for fish hosts), there was no reason to rigorously sample for these organisms within the first 5 or 10 years after the habitat was in place. Therefore, the first intensive mussel survey was conducted in August 2001, 16 years after construction. At that time, a total of 390 mussels representing 13 species were hand-collected in both riffles (Table 1).

The estimated density of live mussels was 0.18 mussels/m². Two species, *O. reflexa* and *Plectomerus dombeyanus*, dominated the fauna (Table 1). The former species ranged in total shell length from 39 to 90 mm, and the latter from 93 to 173 mm (Figures 10a, 10b). Demography for both dominant species illustrates variable recruitment patterns with no obvious dominance of any particular year class (Figures 10a and 10b). The apparent lack of young cohorts is more likely to be the result of difficulty collecting small specimens among the gravelly substratum with moderately high velocity and virtually no visibility—and not

Table 1
Summary of Freshwater Mussels Collected in Both Riffles of the Columbus Gravel Site, August 2001

Species	Number	Percent
<i>Obliquaria reflexa</i>	217	55.64
<i>Plectomerus dombeyanus</i>	129	33.08
<i>Lasmigona complanata</i>	11	2.82
<i>Quadrula apiculata</i>	11	2.82
<i>Quadrula asperata</i>	7	1.79
<i>Lampsilis teres</i>	5	1.28
<i>Actinonaias confragosus</i>	2	0.51
<i>Fusconaia flava</i>	2	0.51
<i>Quadrula rumphiana</i>	2	0.51
<i>Pyganodon grandis</i>	1	0.26
<i>Ellipsaria lineolata</i>	1	0.26
<i>Leptodea fragilis</i>	1	0.26
<i>Lampsilis claibornensis</i>	1	0.26

necessarily due to presence of external stressors. Mussels typically reach their greatest density (50-100 individuals/m²) and richness (25-35) in stable sand and gravel shoals in medium-sized to large rivers in the United States (Miller and Payne 1993, 1998, 2004; Payne and Miller 1989, 2001). However, these rich and dense assemblages are likely the result of many hundreds, or even thousands, of years of development.

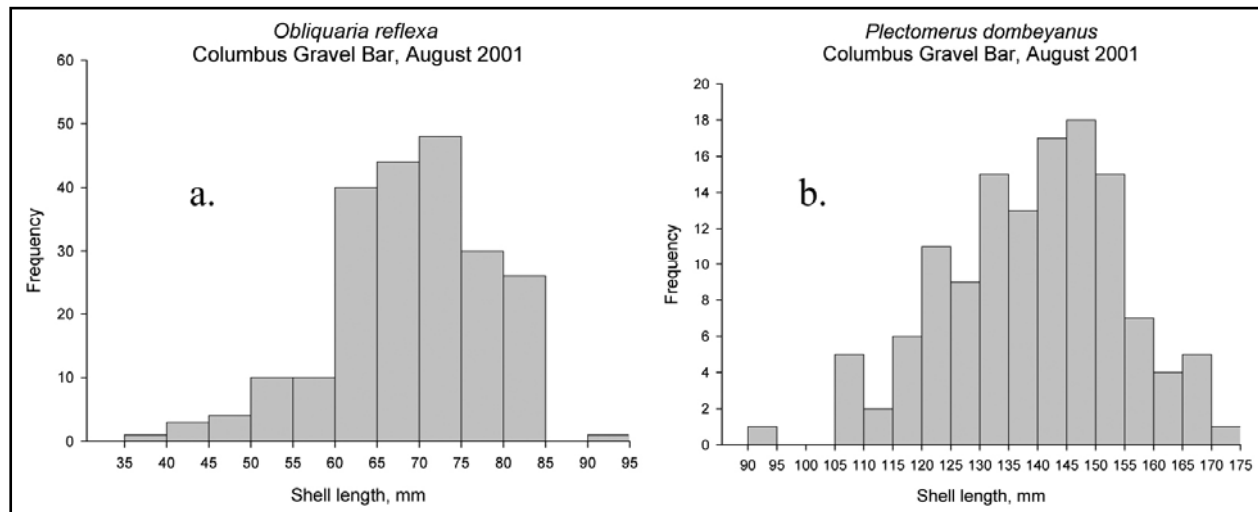


Figure 10. Shell length frequency histogram for a) *Obliquaria reflexa* and b) *Plectomerus dombeyanus*, Columbus gravel bar, August 2001

CONCLUSIONS: The Columbus gravel bar recreated the physical structure of a stable riffle-pool complex, providing habitat for riverine fishes and aquatic insects. The habitat was enriched by plankton from upstream, and unaffected by erosive action of spates that normally affect stream habitats. The shoal was a source of food and cover for riverine species, and a recruitment site for juvenile invertebrates and fishes. The presence of obligate riverine fishes at the gravel bar, such as darters and certain species of minnows, exemplifies the contribution that this habitat can make to maintaining riverine fish populations in an altered river.

Although certain qualitative functional aspects of the habitat were met, these created gravel bars differed from similar natural habitats in that sediments were fairly uniform (there are no boulders or large flat rocks), water velocity did not exceed 45 cm/sec, and there were no pool-riffle sequences immediately up- or downriver. Because it is isolated from other similar habitats, recolonization rates by slowly moving organisms such as the oligochaetes were not as rapid as they would be by more mobile invertebrates. However, on all three sampling dates, total macro-invertebrate density at the created gravel bar exceeded that of natural gravel bars in nearby Luxapalila Creek. This difference was attributed to the lack of periodic spates at the Columbus site, which would have removed the fauna as frequently happens at Luxapalila Creek (Payne and Miller 1991).

Although one of the original goals of the project was to provide habitat for uncommon or even endangered mussel species, so far only common, large-river species have been collected (Figure 11). Flow rates, nutrient content, and water temperatures are much different than in a natural fourth-order stream, such as the nearby Buttahatchie River, which does support uncommon

stream molluscs such as *Pleurobema* sp. and *Epioblasma penita*. Lockwood and Pimm (2001) noted that restoration of a specific species assemblage was listed as a goal 34 times at restored habitats, but only 2 (6 percent) were considered successful. It is easier to restore habitat structure and function than specific species assemblages.

POTENTIAL FOR FURTHER USE: The Columbus gravel bar project, designed to mimic a small portion of the original shallow-water and gravel substratum that was present in the original Tombigbee River, could compensate for only a small percentage of the original lotic habitat lost when the TTW was constructed. Additional minimum flow release structures could be developed similar to the site located near Columbus with very limited financial resources and labor. Gravel could be placed in these areas to encourage fish spawning, and recruitment by mussels and other macroinvertebrates that would provide a food source for fishes of recreational or ecological interest.



Figure 11. Specimen of *Plectomerus dombeyanus* collected from the Columbus gravel bar site in 2001

Any altered waterway likely has sites that could be improved by adding gravel or cobble substratum. The simplest situation would involve adding coarse substratum at sites where adequate flow was present, but the bottom consisted of sand or clay that was not very suitable for macroinvertebrates. In this situation, one would have to be careful that extreme high water did not erode the newly placed material, and that there was sufficient flow during part of the year to keep the sediment clean. Many of the other sites along the TTW that are suitable for similar habitat projects have adequate flow, but do not have suitable substrate. If adequate flow is not present in an alluvial river, it can be provided by constriction with substratum or placement of levees (see Miller et al. (1995)).

POINT OF CONTACT: For more information, contact Dr. Andrew Miller, U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS (Phone: 601-634-2141, Andrew.C.Miller@erdc.usace.army.mil).

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